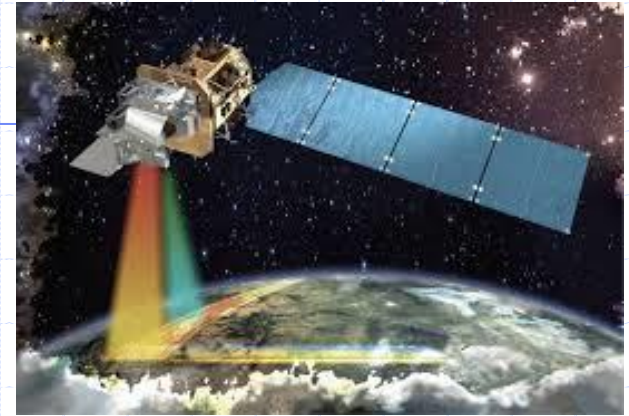


Google Earth Engine Evapotranspiration Flux --- EEFlux



Ayse Kilic, University of Nebraska-Lincoln

Rick Allen, University of Idaho

Justin Huntington, Desert Research Institute

Members of the Landsat Science Team

Doruk Ozturk, University of Nebraska-Lincoln



International Workshop on Evapotranspiration Mapping– Sept. 15, 2015

EEFlux-Development Team

An Evapotranspiration Modeling Tool on Google Earth Engine



Ayse Kilic – University of Nebraska -- Professor, *Member Landsat Science Team*

Justin Huntington – Desert Research Institute – Professor, *Member Landsat Science Team*

Rick Allen -- University of Idaho – Professor, *Member Landsat Science Team*

Doruk Ozturk– University of Nebraska – Developer

Baburao Kamble – University of Nebraska – Developer

Charles Morton – Desert Research Institute – Developer

Ian Ratcliffe – University of Nebraska – Remote Sensing Analyst/Developer

Clarence Robison – Univ. Idaho – GIS technician

Ricardo Trezza – University of Idaho – Professor

David Thau, Google, Inc. – Earth Engine Advocate

Tyler Erickson, Google, Inc. – Earth Engine Advocate

Noel Gorelick, Google, Inc. – Earth Engine Advocate

Rebecca Moore, Google, Inc. – Manager, Earth Engine / *Visionary*



WHAT IS EEFlux?

- Earth Engine Evapotranspiration Flux
- Began in 2012
- Uses the METRIC ET process (thermally-driven energy balance) as foundation
- Operates on the Google Earth Engine and Computational Cloud
- Automated operation and calibration

Why an Evapotranspiration Tool on Google Earth Engine (EE)?

- EE has enormous **computing and storage power**
- EE has essentially **free access**
- EE has strong **developer support**
- ET information is needed across the **Global spectrum**
- Google supports and encourages developers to '**change the world**' regarding access to spatial information on the environment, natural resources, conservation and climate change

Google



The Earth Engine Environment

Earth Engine JavaScript Language and Development “Playground”

The screenshot displays the Google Earth Engine web interface. The top navigation bar includes the Google Earth Engine logo, a search bar, and a user profile dropdown for 'eefluxgeneral2014'. The left sidebar shows a 'Scripts' panel with a list of saved scripts, including 'A_Pecora_Modesto'. The main editor area shows the code for 'A_Pecora_Modesto', which is a JavaScript function for calculating radiation. The right sidebar contains an 'Inspector' panel showing the console output of the script, including values for 'Ts Cold', 'Ts Hot', 'A', 'B', and 'Cold'. The bottom panel shows a map of the Modesto, California area, with a 'Layers' panel on the right side of the map. The 'Layers' panel includes checkboxes for 'Layer 8', 'Layer 7', 'ETiF', 'Ts', 'NDVI', 'Albedo', 'False_Color', and 'True_Color'. The 'ETiF' layer is currently selected. The map view shows a satellite image of the Modesto area, with a 5 km scale bar and a 'Map' button. The bottom status bar shows the map data is from 2014, the scale is 5 km, and the time is 9:09 AM on 11/20/2014.

```
659 return elev.subtract(datum).multiply(lapse_rate * -0.001).add(ts);  
660  
661 // Net Radiation (Rn)  
662 function rn_func (doy, cos_theta, tau, albedo, em_wb, ts, ts_dem_cold) {  
663   // Net Incident & Reflected Longwave Radiation  
664   var rl_in = tau.log().multiply(-1).pow(0.09).multiply(0.85 * 5.67E-8)  
665   // Use NLDAS air temperature  
666   // .multiply(ta.add(273.15).pow(4));  
667   // Use delapsed Ts_dem at the cold calibration point  
668   .multiply(ts_dem_cold.pow(4));  
669   // Emitted Longwave Radiation  
670   var rl_out = ts.pow(4).multiply(em_wb).multiply(5.67E-8).add(rl_in)  
671   .subtract(rl_in.multiply(em_wb));  
672   // Shortwave Radiation
```

Inspector Console

Use print(...) to write to this console.

Ts Cold: 2... JSON

Ts Hot: 31... JSON

A: 0.80738... JSON

B: -229.52... JSON

Cold: 0.91... JSON

Layers

☐ Layer 8

☐ Layer 7

☒ ETiF

☐ Ts

☐ NDVI

☐ Albedo

☐ False_Color

☐ True_Color

Map Satellite

Map data ©2014 Google 5 km Terms of Use Report a map error

Desktop 9:09 AM 11/20/2014

Modesto, California (Central Valley) area
Monitoring impacts of drought

Google Earth Engine Evapotranspiration Flux - EEFlux

<http://eeflux-level1.appspot.com>

False Color Composite



2015-08-17 / LC80150332015229LGN00

Products

BASE MAP

TRUE COLOR

FALSE COLOR (4, 3, 2)

FALSE COLOR (7, 5, 3)

ALBEDO

NDVI

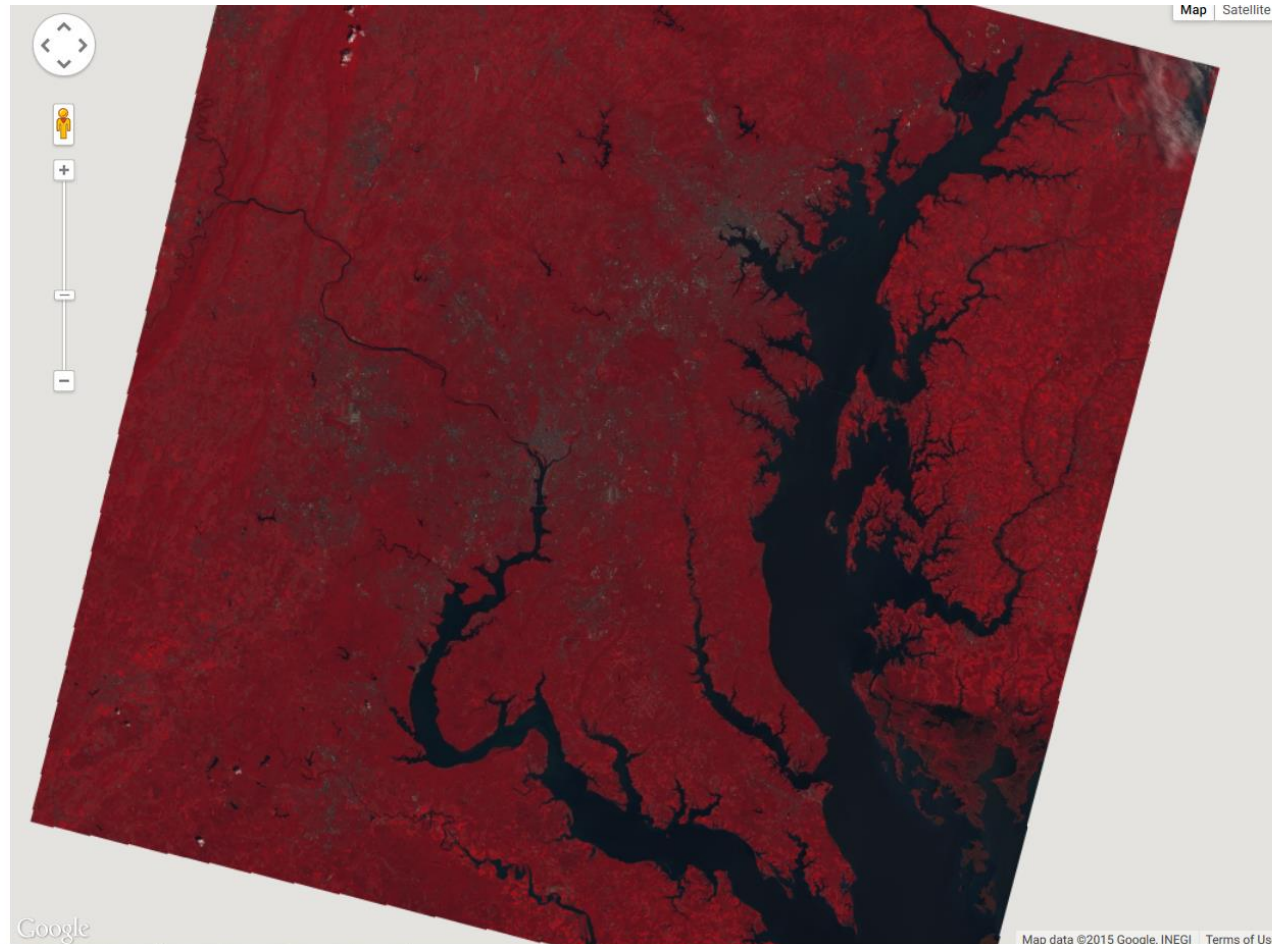
DEM

LAND COVER

SURFACE TEMPERATURE

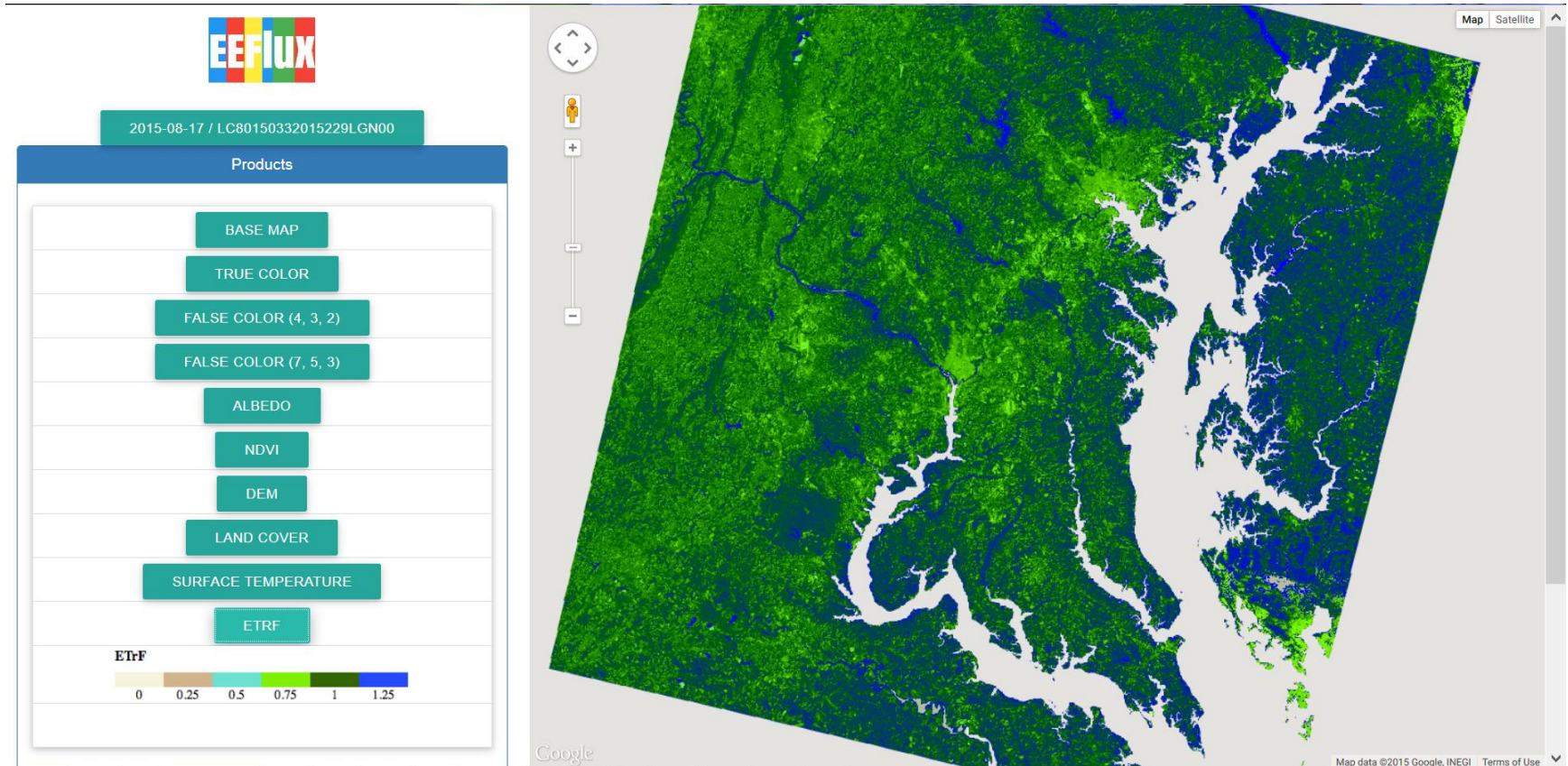
ETRF

DOWNLOAD ETRF



Google Earth Engine Evapotranspiration Flux - EEFlux

ET_rF--Fraction of Reference ET



$$ET_rF = ET / ET_{ref}$$

ET_{ref} is reference ET- ASCE-Penman Monteith Alfalfa reference

Google Earth Engine

Evapotranspiration Flux --- EEFlux

Albedo



2015-08-17 / LC80150332015229LGN00

Products

BASE MAP

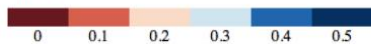
TRUE COLOR

FALSE COLOR (4, 3, 2)

FALSE COLOR (7, 5, 3)

ALBEDO

Albedo



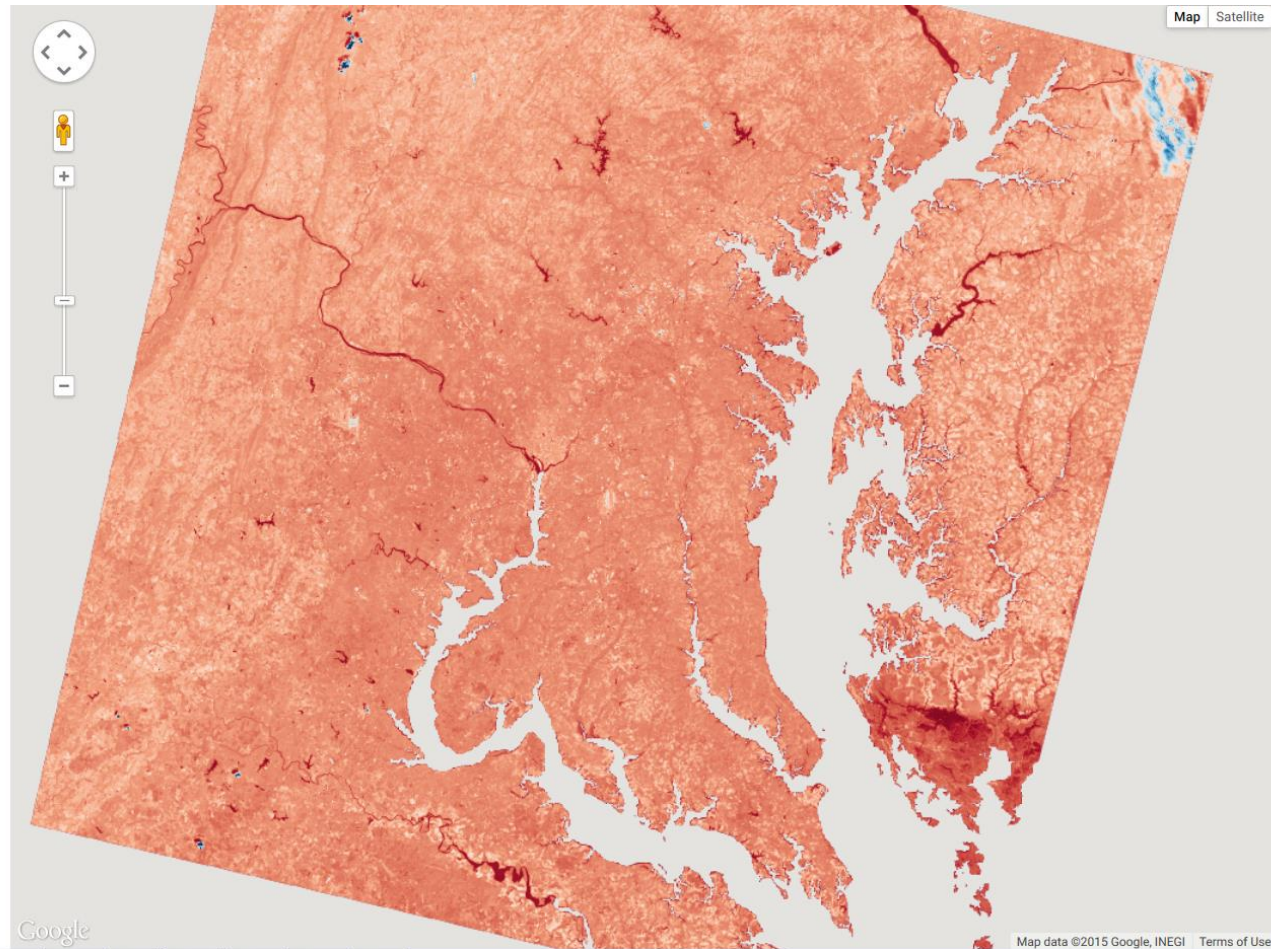
NDVI

DEM

LAND COVER

SURFACE TEMPERATURE

ETRF



Google Earth Engine

Evapotranspiration Flux --- EEFlux

NDVI--Normalized Difference Vegetation Index



2015-08-17 / LC80150332015229LGN00

Products

BASE MAP

TRUE COLOR

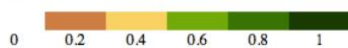
FALSE COLOR (4, 3, 2)

FALSE COLOR (7, 5, 3)

ALBEDO

NDVI

NDVI



DEM

LAND COVER

SURFACE TEMPERATURE

ETRF



Google Earth Engine

Evapotranspiration Flux --- EEFlux

NLCD - Landuse



2015-08-17 / LC80150332015229LGN00

Products

BASE MAP

TRUE COLOR

FALSE COLOR (4, 3, 2)

FALSE COLOR (7, 5, 3)

ALBEDO

NDVI

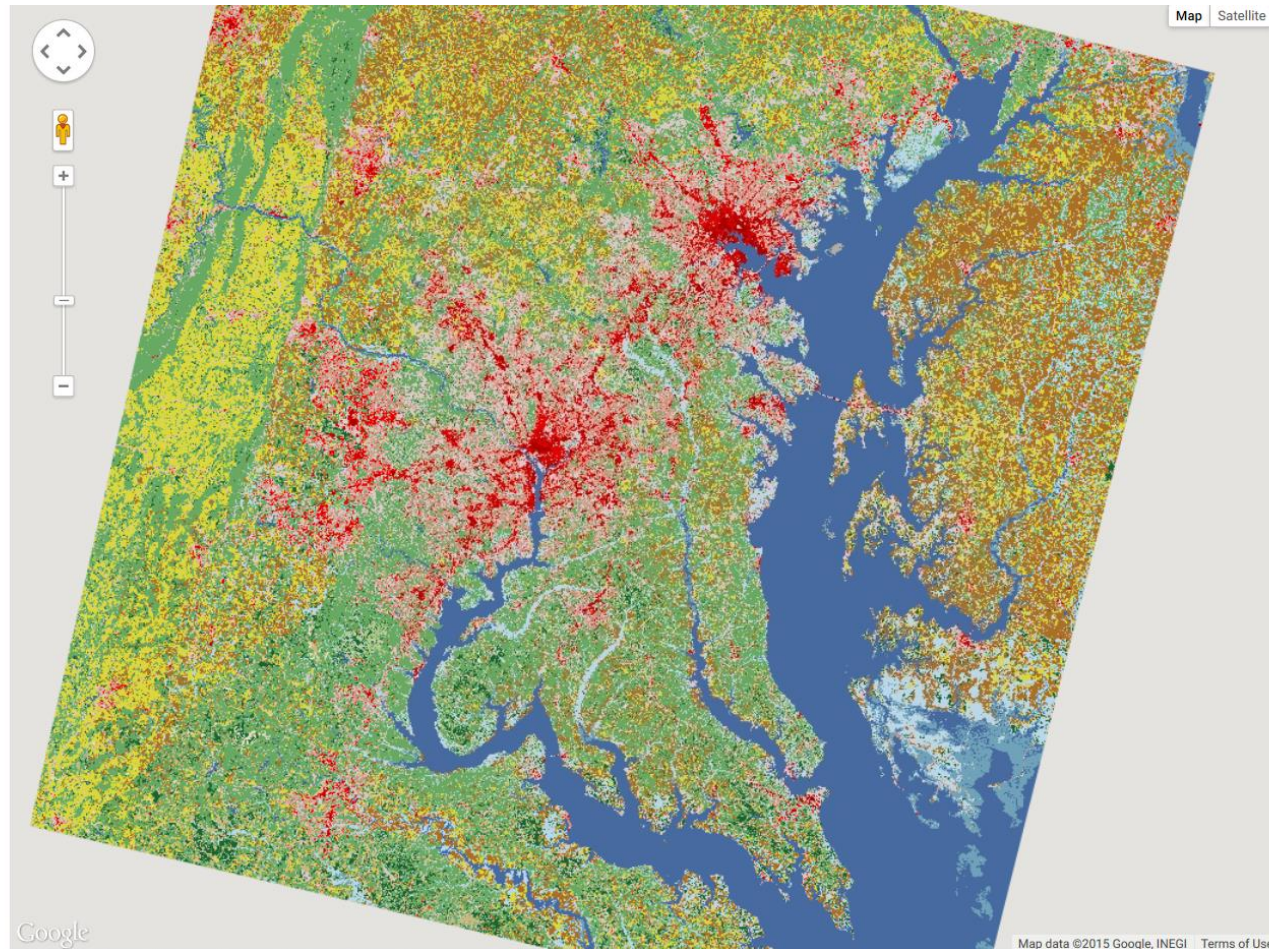
DEM

LAND COVER

SURFACE TEMPERATURE

ETRF

DOWNLOAD ETRF



<http://eeflux-level1.appspot.com>

Google Earth Engine

Evapotranspiration Flux --- EEFlux

Surface Temperature (K)



2015-08-17 / LC80150332015229LGN00

Products

BASE MAP

TRUE COLOR

FALSE COLOR (4, 3, 2)

FALSE COLOR (7, 5, 3)

ALBEDO

NDVI

DEM

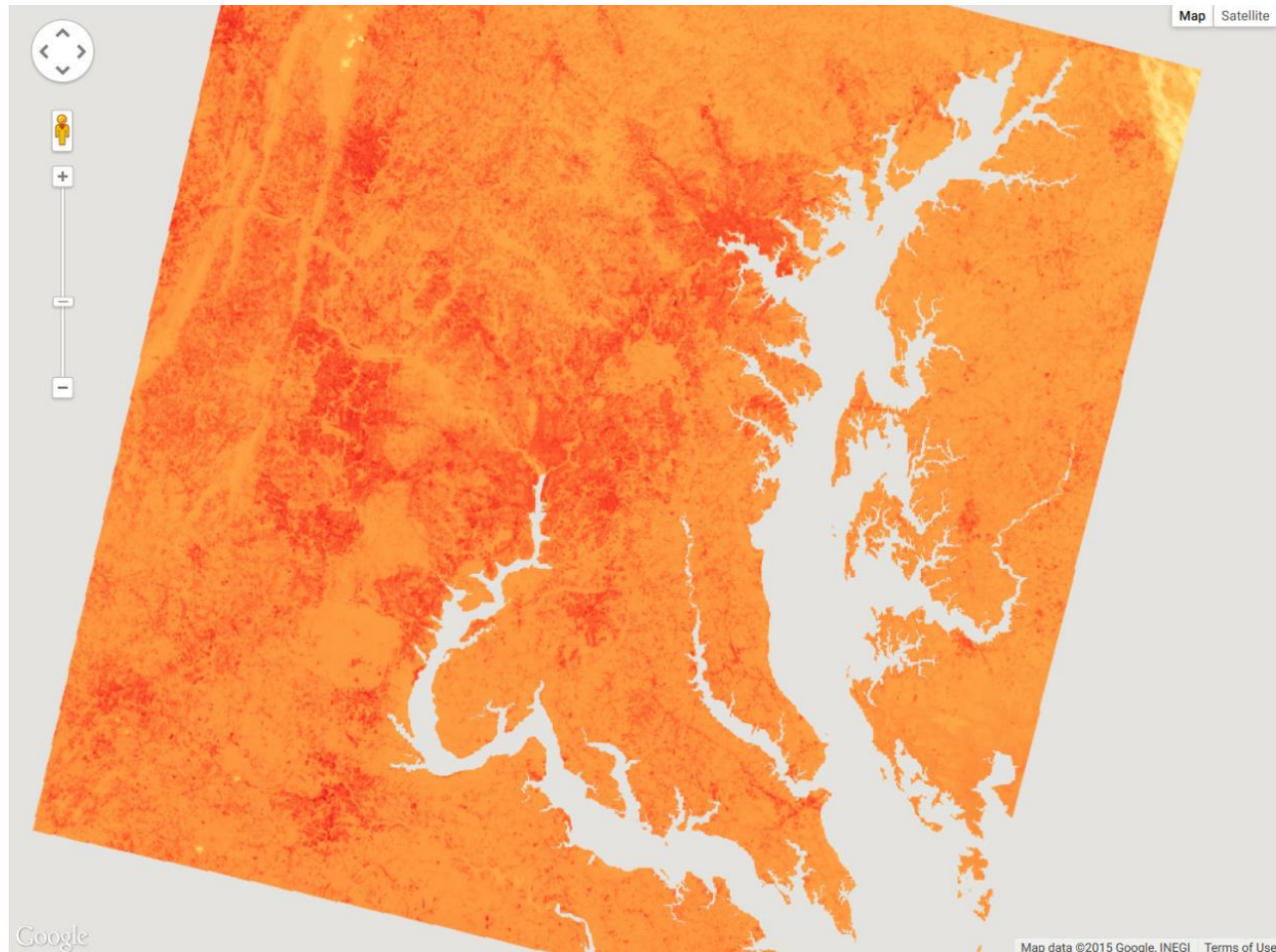
LAND COVER

SURFACE TEMPERATURE

Surface Temperature

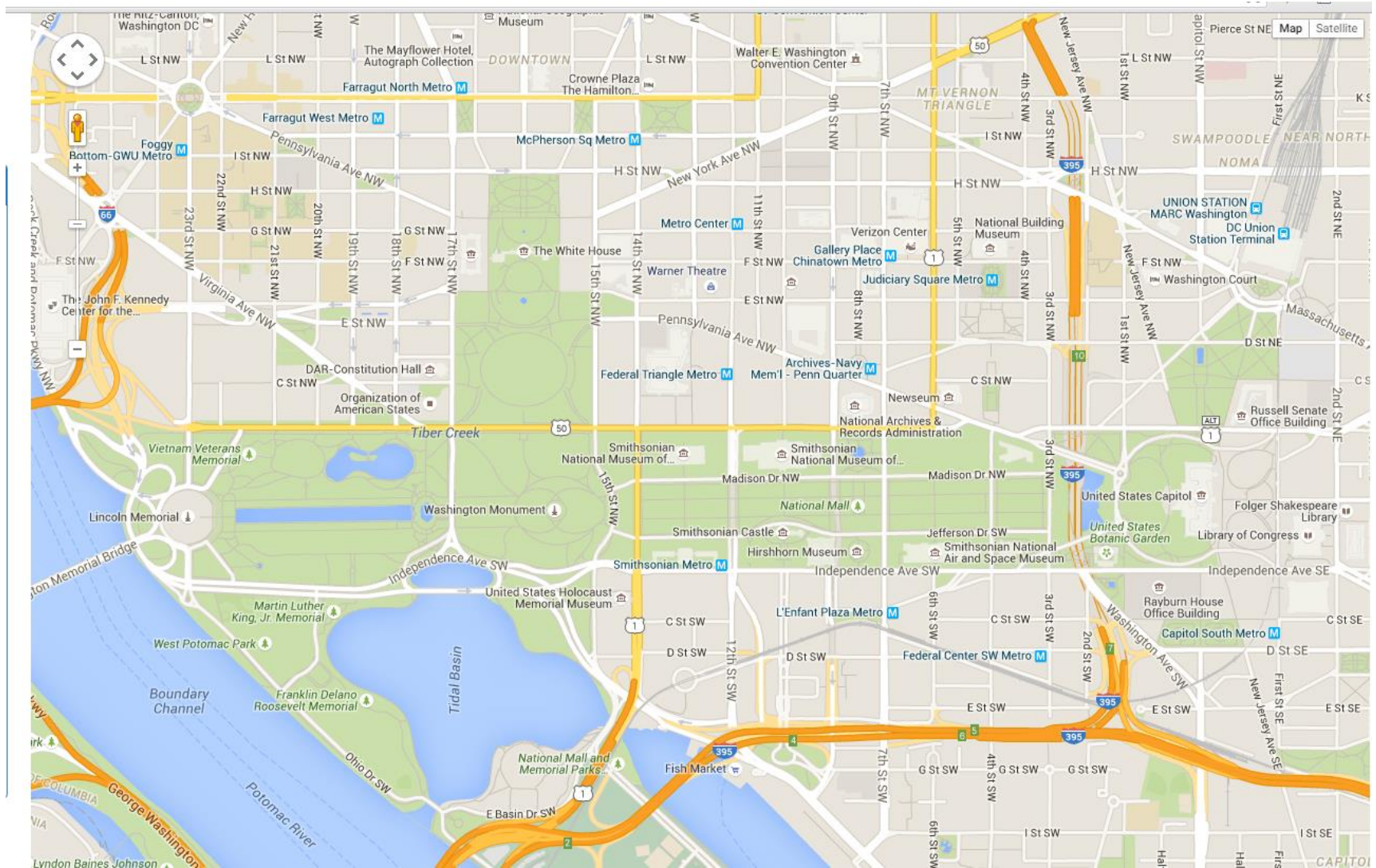


ETRF



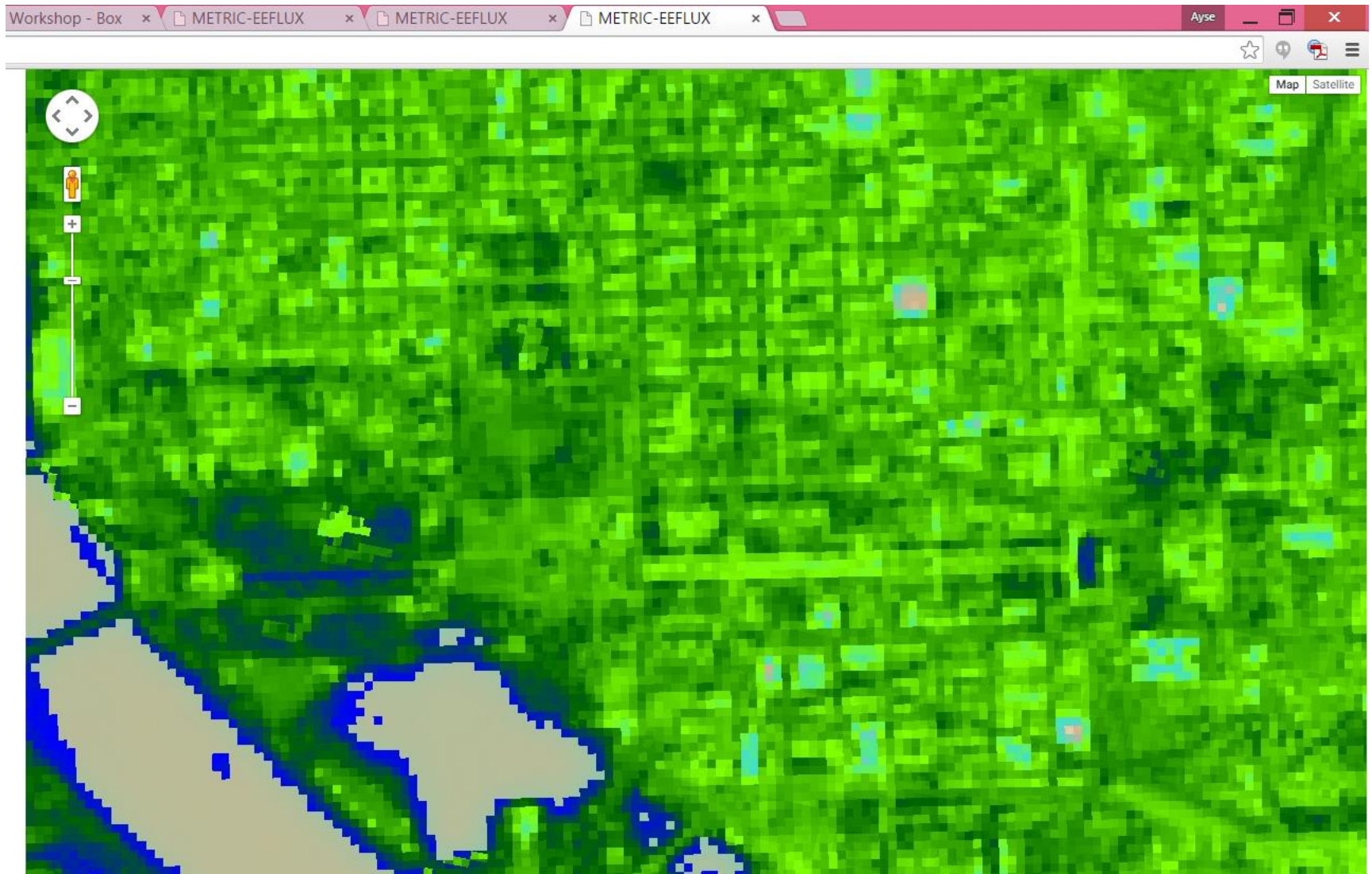
BASE MAP- NATIONAL MALL, WASHINGTON, DC

August 17, 2015



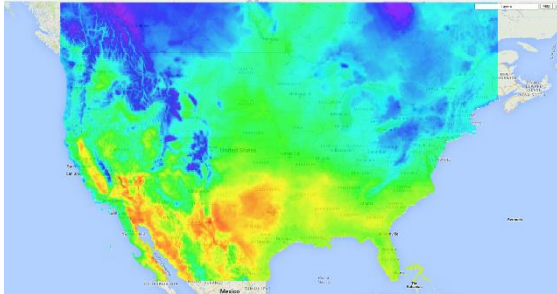
ETrF MAP- NATIONAL MALL, WASHINGTON, DC

August 17, 2015

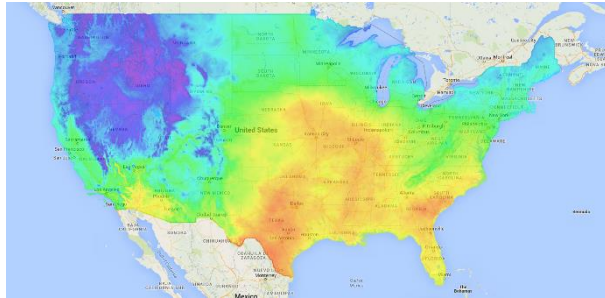


Data Resources Used by EFlux

NLDAS-Jan 1, 1979 - Current



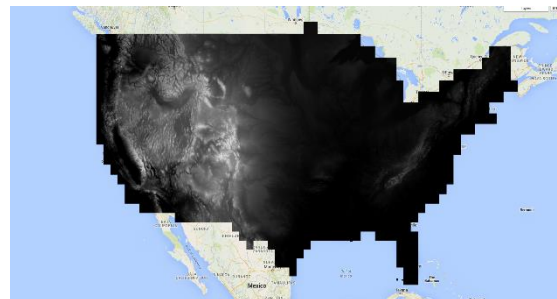
GRIDMET-Jan 1, 1979 - Current



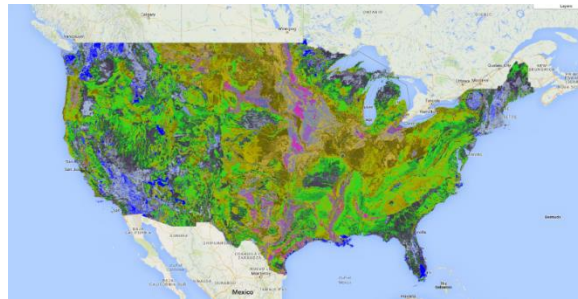
Landsat 5/7/8



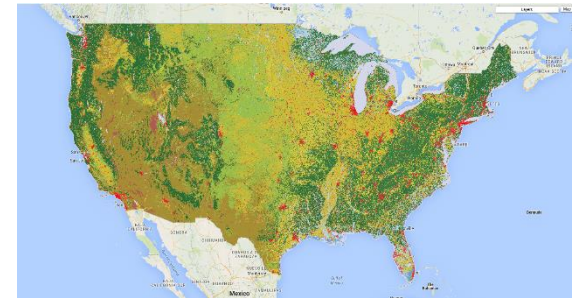
DEM



Soil Data Layers



NLCD Landuse

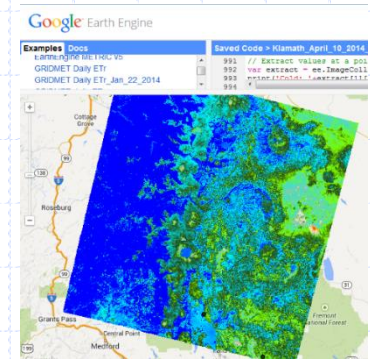


These data products are loaded and are functional on Earth Engine

<http://eeflux-level1.appspot.com>

Data Resources Used by EEF_lux

- Landsat 5/7/8 and MODIS
- Gridded Weather Data – used to calibrate EEF_lux energy balance and to calculate Reference ET used for Time Integration of ET:
 - NLDAS – North American Land Data Assimilation System
 - hourly weather data at 12 km available for > 30 year period for CONUS
 - GridMET - daily, bias corrected weather data at 4 km available for > 30 year period for CONUS
 - Climate Forecast System Version 2, 6-hourly Product (CSFV2)—nonCONUS
 - Real Time Mesoscale Analysis (RTMA) – downloaded daily to Earth Engine – used to fill in time gaps between NLDAS and today for processing recent Landsat imagery
- Soils -- Used to produce a daily time series of evaporation from bare soil.
 - Statsgo soils data is available for CONUS for top 0.15 m of soil
 - FAO soils data base & Global Soil database by Wei Shangguan et al. 2014)
- Landuse (NLCD) and Global Land Cover from European Space Agency:
<http://www.esa-landcover-cci.org/>
- Digital Elevation Maps

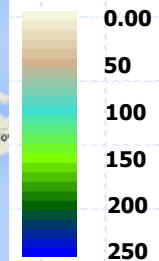


Klamath, 2014

ET between Landsat dates is scaled using Reference ET



Reference ET (mm/mo)



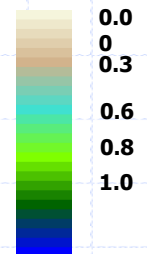
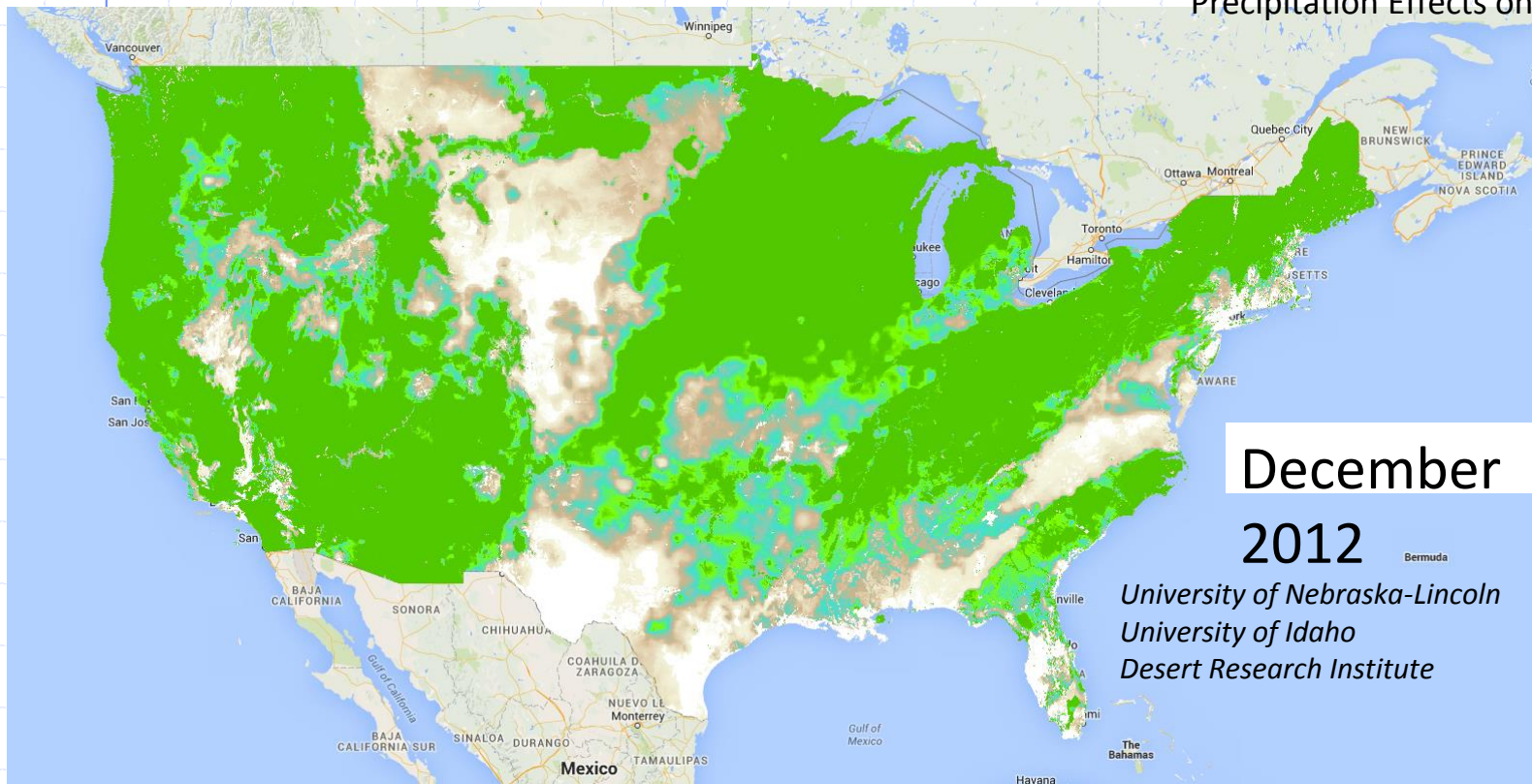
Reference ET is calculated using the ASCE Standardized Penman-Monteith Equation for the Tall Reference (Alfalfa)

--computed from the daily GridMET data set of Abatzoglou (2012)

Univ. Nebraska-Lincoln, Desert Research Institute, Univ. Idaho

The Soil Surface Evaporation Component of the Google Earth Engine EEFlux App.

--- Evaporation from Bare Soil --- used
to calibrate the EEFlux
Evapotranspiration Surface Energy
Balance to account for background
Precipitation Effects on ET Evap. Coef. (K_e)



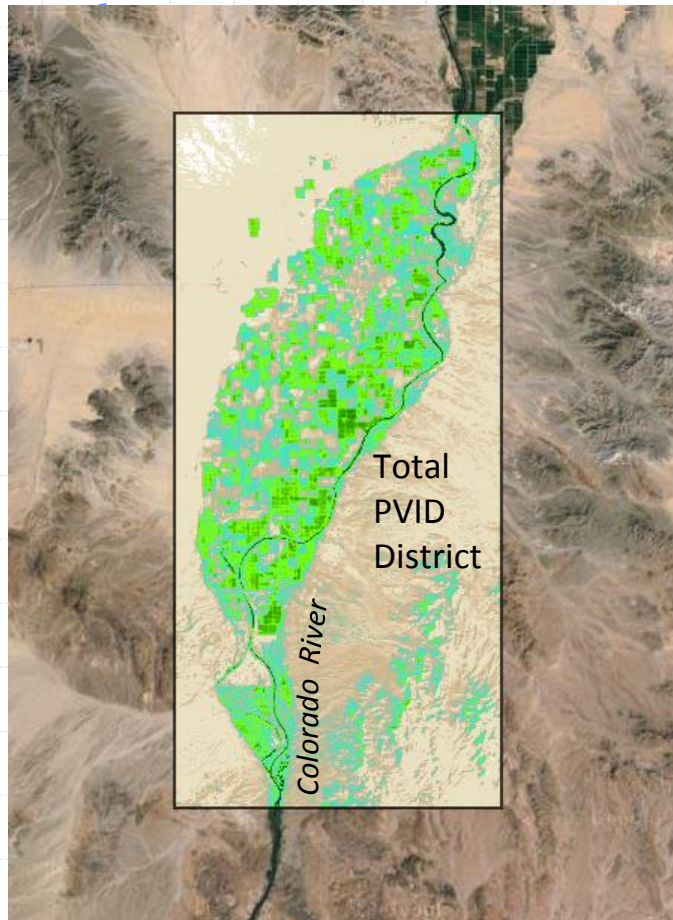
$$(K_e = E_{act} / ET_{ref})$$

December
2012

University of Nebraska-Lincoln
University of Idaho
Desert Research Institute

--computed
from the
GridMET
weather data set
of Abatzoglou
(2012)
-- GridMET is
traceable to
NLDAS and
PRISM data sets

Google Earth Engine Flux --- EEFlux

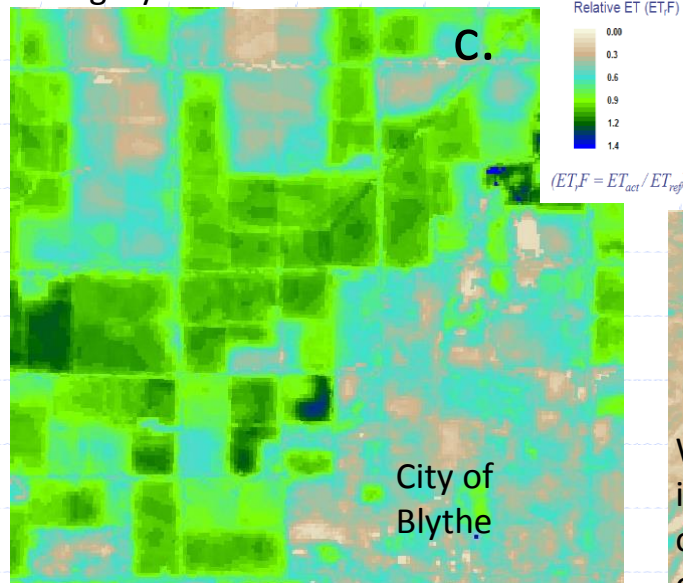


Earth Engine Evapotranspiration Flux

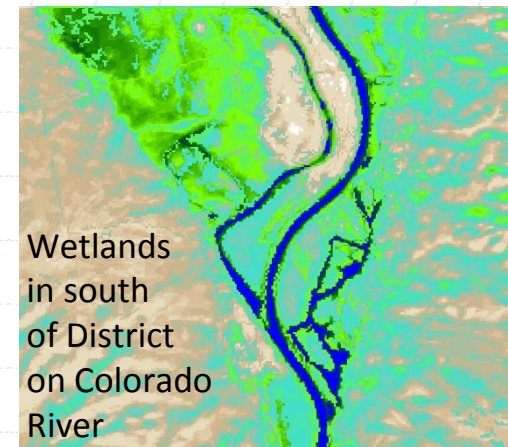
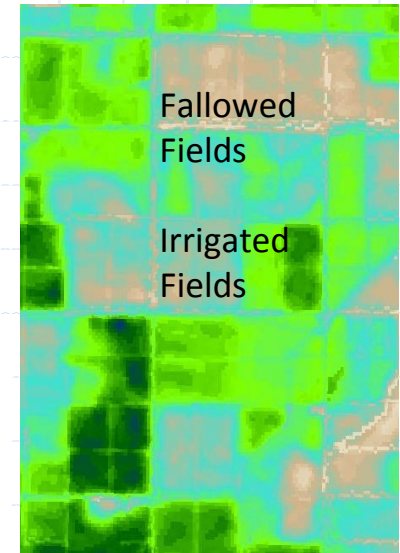
Palo Verde Irrigation District

Blythe, California – Jan. – Dec. 2008

-- Landsat 5
imagery



Univ. Nebraska-Lincoln, Univ. Idaho, Desert Research Institute



Computations are based on a complete surface energy balance (*METRIC*)

Water Literacy

- ◆ The law conservation of mass dictates that only ET is lost from the liquid water system.
- ◆ An Informed, voting public needs to be water literate
- ◆ Having free, ready access to ET information is part of that literacy

Why we have used Landsat?

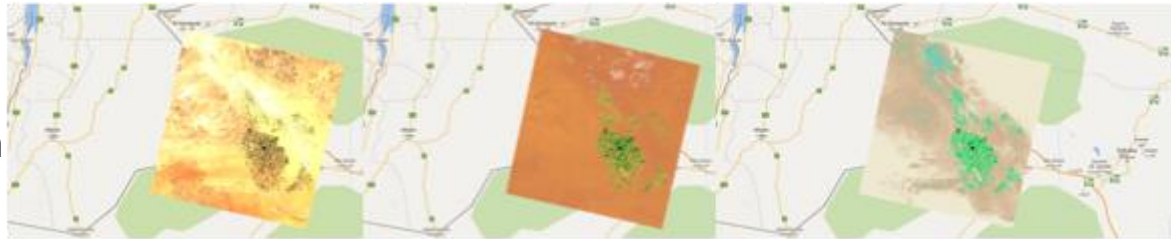
- ◆ We know the importance of field scale ET maps for even the general Google community
- ◆ We recognize that water management and water rights began at the field level
- ◆ We want all Americans to have the opportunity and resources to be water literate

EEFlux Applications around the Globe

Imperial Valley
and Palo Verde,
CA



Jordan

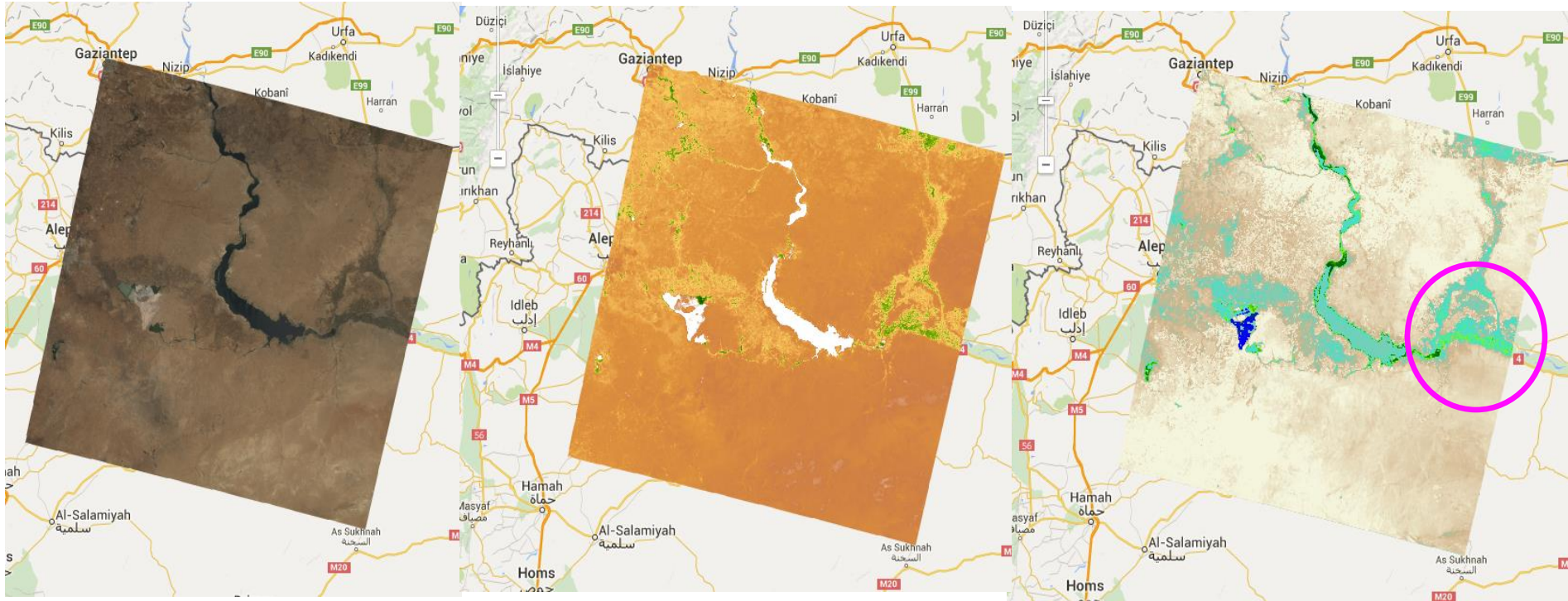


Chile



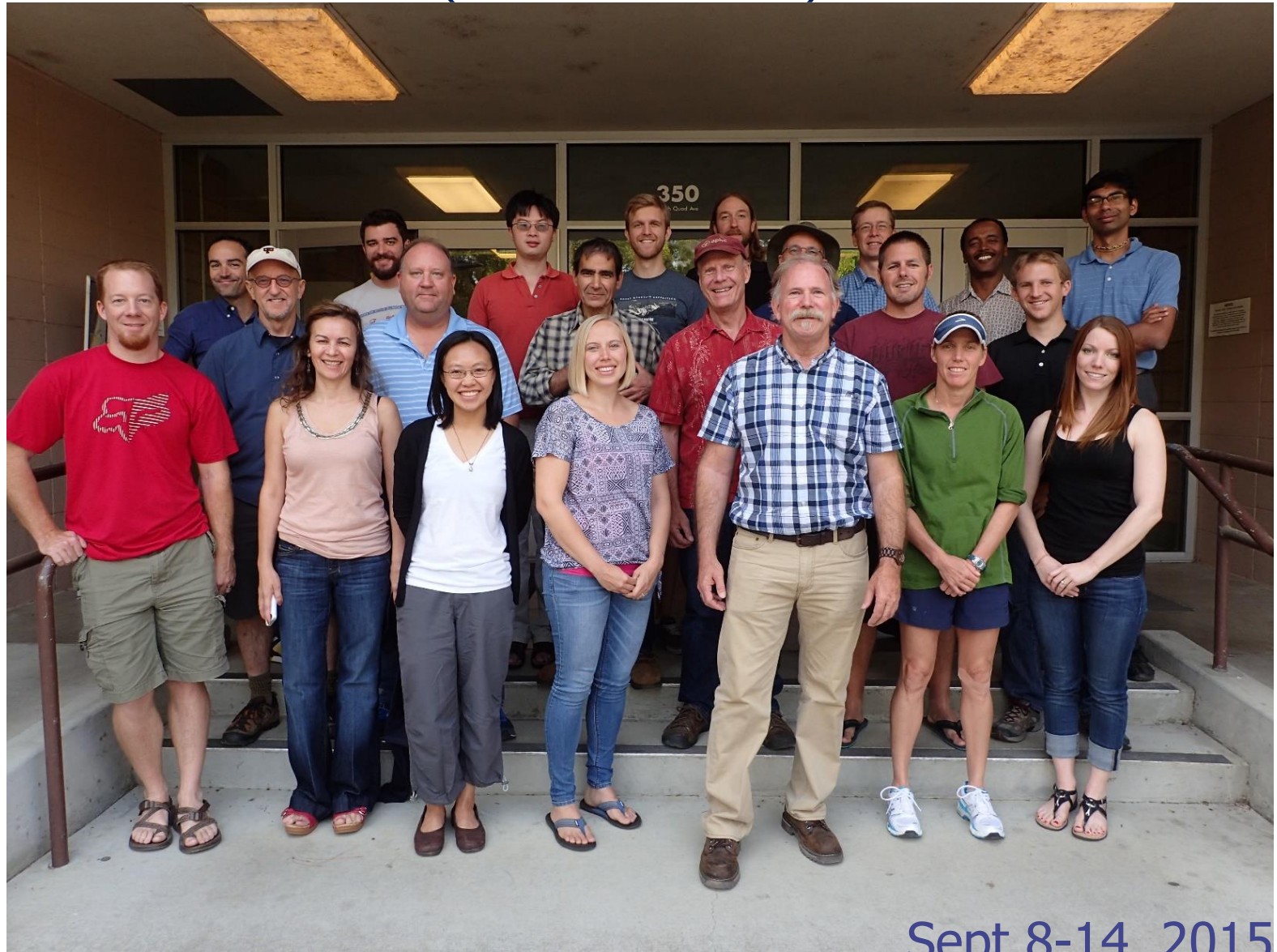
We are testing EEFlux over the globe in a number of Countries and Conditions

EEFlux Applications around the Globe



ET (right) around the city of El Raqqa, Syria on the Euphrates River in 2015, showing reduced ET following the takeover by rebels.

2015 METRIC/EEFLUX TRAINING at UC DAVIS, CA
ORGANIZER: CALIFORNIA DEPARTMENT OF WATER RESOURCES
(27 PARTICIPANTS)



Sept 8-14, 2015

Next Steps

Automation of:

- **Advanced** Cloud detection and mitigation
- Time integration to produce monthly and annual ET volumes
- Mosaicing paths

Release of a User Console

- Permit some degree of tuning (calibration utility)
- Save project information

Level 2 EEFLux – Manual refinement of the Calibration



----Nearly ready for release. -- Will require licensing



RE-RUN EEFLUX

GO BACK

This table will be populated with values sampled from the locations of the red (hot) and blue (cold) locators on the map.

Values	Hot Pixel 	Cold Pixel 
Latitude	0	0
Longitude	0	0
NDVI	0.16	0.87
Surface Temperature	327.75	304.98
Albedo	0.18	0.16
Land Use	82	82
Elevation	32.78	25.13

You can specify new ETrF values to use for the two locations selected for an improved calibration

ETrF hot

0.10

ETrF cold

1.05

